Thermodynamic Properties of Gases and Liquids Determined from the Speed of Sound (Invited)

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Modern experimental techniques allow the speed of sound to be measured in compressed gases and liquids with high accuracy and over wide ranges of temperature and pressure. The use of spherical acoustic resonators for measurements in gases is now routine. At Imperial College, we have applied this method to a number of pure gases and mixtures at temperatures between 100 K and 475 K with pressures as high as 30 MPa. The total uncertainty of the measurements typically ranges from better than 0.001 per cent for a pure gas at pressures near 1 MPa to about 0.02 per cent for gas mixtures at 20 MPa. In the case of liquids, pulsed techniques are common and we are equipped with a double-path pulse-echo apparatus capable of an uncertainty of about 0.02 per cent at pressures up to 200 MPa. Results for a number of fluids, illustrating the capabilities of both measurement techniques, will be presented.

The primary motivation for measuring the speed of sound is to gain information about other thermal and caloric properties of the medium. These thermodynamic properties may be determined from the acoustic results in a number of ways. One method is to assume, either explicitly or implicitly, a functional form for the equation of state containing a set of parameters, the values of which are fitted to the experimental speeds of sound. This approach has proved to be remarkably successful for gases provided that the equation of state is one based upon reliable molecular theory. A second general strategy by which thermodynamic properties may be determined from the speed of sound involves numerical integration of the differential equations which link these properties. This method may be applied in appropriate forms to both gases and liquids but initial values of, typically, density and heat capacity are required along at least one thermodynamic path in addition to knowledge of the speed of sound over the whole surface of interest. Examples illustrating the strengths and limitations of both general approaches will be presented.

Finally, the design and usefulness of sound-speed sensors for industrial applications will be discussed.